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PREPARATION OF DATA FROM THE BAIRD-ATOMIC AIRBORNE INFRARED RADIOMETER

H. G. ELDERING

September 1968

BACKGROUND ANALYSIS CENTER
INFRARED AND OPTICAL SENSOR LABORATORY
Willow Run Laboratories
THE INSTITUTE OF SCIENCE AND TECHNOLOGY

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PREFACE

The Background Analysis Center has been established at the Willow Run Laboratories of the Institute of Science and Technology within the Infrared and Optical Sensor Laboratory, under Contract SD-91 with the Advanced Research Projects Agency. The Center's functions are the collection and review of pertinent documents, storage and analysis of background data, and the investigation of background discrimination techniques.

The collection and review of documentation pertaining to background measurements, theoretical analysis of background radiation, and background discrimination techniques are the basis of the information dissemination activities of the Center. This information and consultation with Center staff members are available to qualified investigators. Summaries of current state-of-background knowledge are published.

The background data collection, storage, and analysis can be considered in three phases. First, raw data is prepared in standard form. Second, the obvious summary statistics are computed for each set of data. Third, proposed background models are compared with the experimental data; this comparison is intended to improve the state of knowledge concerning radiation backgrounds.

The third activity of the Center is the investigation of proposed techniques for background discrimination. Particular emphasis is laid upon uncovering the type of background data required to implement a proposed discrimination scheme and upon defining the types of discrimination techniques that show promise in the light of current background information.

Baird-Atomic, Incorporated, personnel who participated in the work being reported here included Herman G. Eldering, William G. Elliott, William G. Langton, Daniel Watanabe, Edward Sabbagh, Dr. James Cunningham, Frank Dow, Gerald Harrington, Charles Hardie, Fay Simons, Arlene Ward, and Eugene Black. They obtained some programming assistance from Philip Hankins and Charles McCarthy of Philip Hankins and Company, and some statistical analysis assistance from Dr. Julian Bussgang and Leonard Ehrman of Signatron, Incorporated.

Participating personnel from The University of Michigan were J. Penquite, R. Legault, R. Kauth, W. Evans, W. A. Wheaton, and A. Krause, and they received assistance from G. Brown, J. Rodnite, R. Cole, and K. Gordon of Information Control Systems, Incorporated.

ABSTRACT

Infrared background-radiance measurements obtained from a U-2 aircraft platform were digitized and prepared for analysis with ancillary data such as cloud type and scattering angle incorporated. The final prepared form described in this report allows easy access to the data by using an IBM 7090 computer or other computers which can read seven-track, 1/2-in. IBM binary tape format at 556 bits/in. A data unpacking subroutine written in assembly language for the 7090 is also described. Some results of analysis of these data are presented here, and other analysis results are referenced.

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CONTENTS

FIGURES

TABLES

PREPARATION OF DATA FROM THE BAIRD-ATOMIC AIRBORNE INFRARED RADIOMETER

1
INTRODUCTION

A spatially scanning filter-wheel radiometer was designed, built, and operated in a U-2 aircraft by Baird-Atomic, Incorporated, in order to gather cloud radiance data in the 1.8- to 4.5-μ region during 1960 and 1961. The data were analyzed in analog form [1] and later converted to digital form [2] and analyzed [3]. The data were then transferred to the Background Analysis Center (BAC) at Willow Run Laboratories, a unit of The University of Michigan's Institute of Science and Technology, where they were converted to final prepared form and analyzed.

This report reviews the measurement equipment and its calibration in section 2. The data digitization and preparation are discussed in section 3, while section 4 contains some elementary analysis to provide insight into the way the data may be analyzed. A more comprehensive data analysis, conducted using these data and data from other experiments, is presented in reference 4.

2
MEASUREMENT EQUIPMENT AND CALIBRATION

2.1. MEASUREMENT PROGRAM

With a U-2 aircraft as the high-altitude platform and with the equipment specifically described in section 2.2, measurements were made of the absolute radiance in the 2- to 3-μ spectral region and of the local radiance differences in the spectral region from 1.8 to 5 μ. The flight programs for recording these data encompassed three different geographical areas in the northern half of the Western Hemisphere under various meteorological and seasonal conditions so that a more accurate evaluation of the background might be obtained (see fig. 1). The flights were distributed from dawn to twilight to provide a sample with varying solar illumination. In addition, two flights were made in support of a satellite background-measurement program. The purpose of these was to obtain aircraft infrared background measurements comparable to the satellite measurements and to provide photographic coverage of the satellite track.

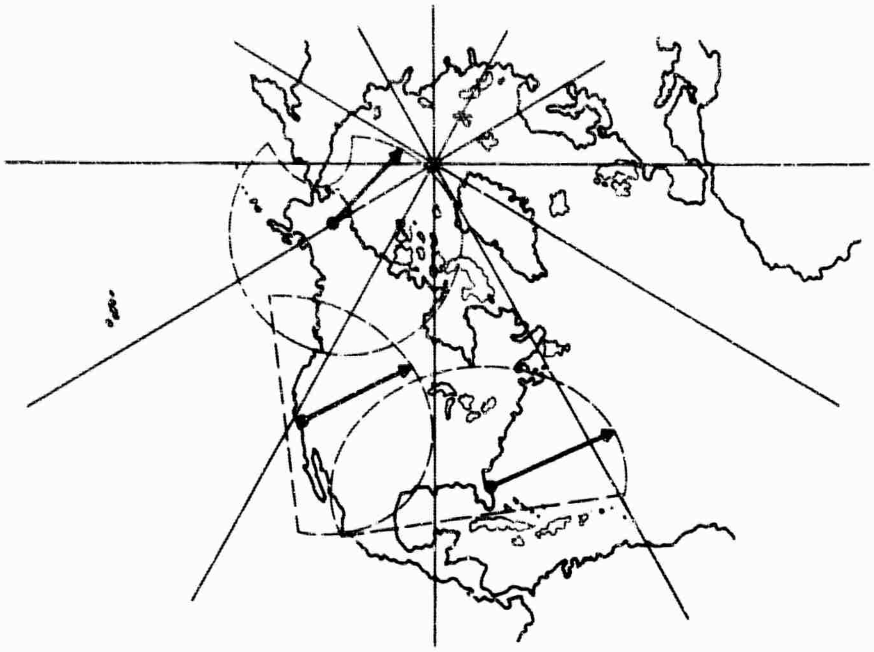


FIGURE 1. REGIONS WHERE MEASUREMENTS WERE MADE

2.2. BACKGROUND RADIATION SCANNER

The background radiation scanner (fig. 2) consists of collecting optics, elevation scanning mirror, detectors, preamplifier, inflight calibration system, and boresight camera in the lower turret assembly extending beneath the aircraft, and the azimuth drive system, cable wind-up mechanism, additional electronics, and all connectors in the upper turret assembly. The tape recorder, oscillograph, and remaining electronics were mounted in the airplane equipment bay. The characteristics of the scanner are summarized in table I.

2.2.1. OPTICAL SYSTEM. Figure 3 is a schematic of the scanner's optical system showing the plane scanning mirror, parabolic focusing mirror, spherical insert mirror, filter disc, and calibration system. The spherical mirror inset into the parabola has a radius of curvature equal to the latter's focal length, and its shape is determined by the projection of the hole in the scanning mirror. Therefore the detector views itself instead of the interior of the scanner in the area corresponding to the scanning-mirror hole. The extreme rays reaching the detector are limited by a cold cylinder within the Dewar rather than by the perimeter of the parabola. This prevents rays from the emissive mirror mounting from reaching the detector.

FIGURE 2. BACKGROUND RADIATION SCANNER

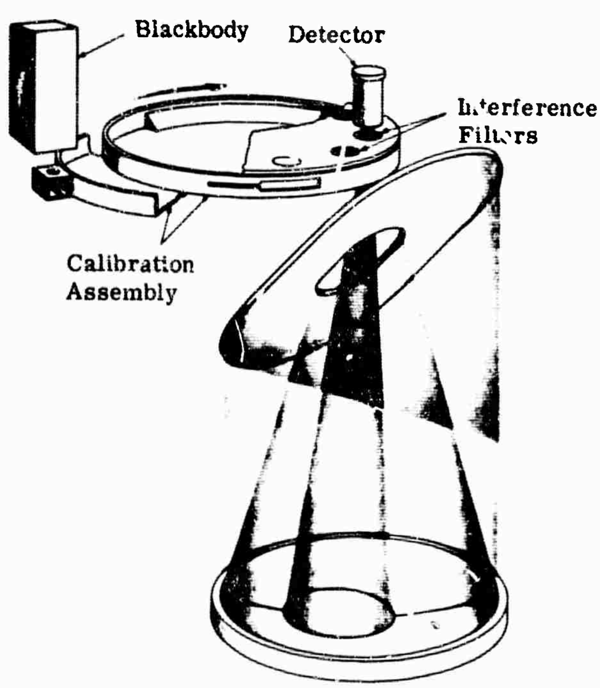


FIGURE 3. SCHEMATIC OF THE SCANNER'S OPTICAL SYSTEM

TABLE I. CHARACTERISTICS OF THE
BACKGROUND RADIATION SCANNER

Optical

Mirror

Effective area: 250 cm^2
Focal length: 36.6 cm

Detector (PbSe or PbS)

Elements 1, 3: 1 × 3 mm
Elements 2, 4: 1 × 2 mm

Electrical

Dynamic Range: 40 db

Frequency response

Upper 3-db frequency: 150 cps
Lower 3-db frequency: 7 cps with PbSe Detector, 1.5 cps with PbS Detector

Sensitivity

Noise-equivalent flux density (filter 2): $\sim 10^{-12}$ w/cm^2

Mechanical

Scan rates

Slow: 1^{o}/sec
Fast: 24^{o}/sec

Scan limits

Azimuth: $\pm 131^{o}$ from nose
Elevation: 64 to 92^{o} from nadir

The filter disc has space for ten interference filters. The distance between filters equals the filter diameter. The surface of the disc facing the detector is optically polished and coated with a multilayer interference film to provide an optimum reflecting surface. Any interference filter may be selected upon command by the pilot for relative radiance measurements; the filter disc is rotated at 300 rpm during absolute radiance measurements. When the interference filter is in position, the detector sees itself and its cold shield at all wavelengths not transmitted by the filter, the energy transmitted through the filter from the scene being measured, and the energy emitted by the filter. When the filter is rotated so that the reflective surface of the disc

fills the detector field, the detector sees only itself and its cold shield, as reflected by the surface of the disc, and the energy emitted by the disc. The coatings on the disc and filter were matched as closely as possible. As the disc rotates, a second disc on the same shaft generates pulses identifying the positions of the filters.

During internal calibration, the baffle in the calibration system is rotated to block off external radiation from the detector and to "see" the interior of the calibration assembly. A 45° mirror mounted on the baffle moves beneath the detector and reflects the assembly's interior toward the detector for 15 sec. After this, a horizontal slit in the moving baffle lines up with a vertical slit in front of the stationary mirror beneath the blackbody and admits energy from the blackbody to the moving mirror. This mirror deflects the energy to the detector. This measurement continues for 15 sec. Then, a wider horizontal slit appears in front of the vertical slit to admit twice as much energy to the detector, and this measurement also continues for 15 sec. The baffle then returns to its original position, and energy from the parabola again reaches the detector.

Figure 4 shows a cutaway view of the lead selenide (PbSe) detector assembly. It consists of four separate elements arranged in a cross. Surrounding the detector and mounted to the cooling stem is a cylindrical shield which acts as the limiting aperture of the optical system. Adjacent to the detector and supported by the cylindrical shield are two cold filters which limit the long- and short wavelength response of the detector. One filter is a piece of coated germanium 0.062 in. thick, while the other is quartz 0.012 in. thick. A sapphire window is mounted on the end of the Dewar, and the entire glass package is encapsulated in an aluminum mounting assembly. A specially designed cooling probe fits into the rear of the aluminum housing. Liquid nitrogen is supplied to the cooling probe by a transfer system. An uncooled lead sulfide (PbS) detector has also been mounted in similar housing and may be used interchangeably with the PbSe detector.

2.2.2. MODES OF OPERATION. Operation of the scanner is controlled from the cockpit. Six modes of operation are available to the pilot. In the "stow" position, the equipment looks to the rear of the aircraft to protect the entrance window during takeoff and landing. In the "calibrate" mode, the calibration subassembly rotates to provide internal calibration as previously described. In the "slow azimuth" mode, the scanner rotates at 1°/sec in azimuth, while the filter wheel rotates at a rate sufficiently high so that the filters go through one complete cycle before the scanner has moved through one field of view. This provides the absolute radiance measurements as previously indicated. While in the "fast azimuth" mode, the scanner rotates at 24°/sec, and the filter wheel moves to the position selected by the pilot. In this mode, filters

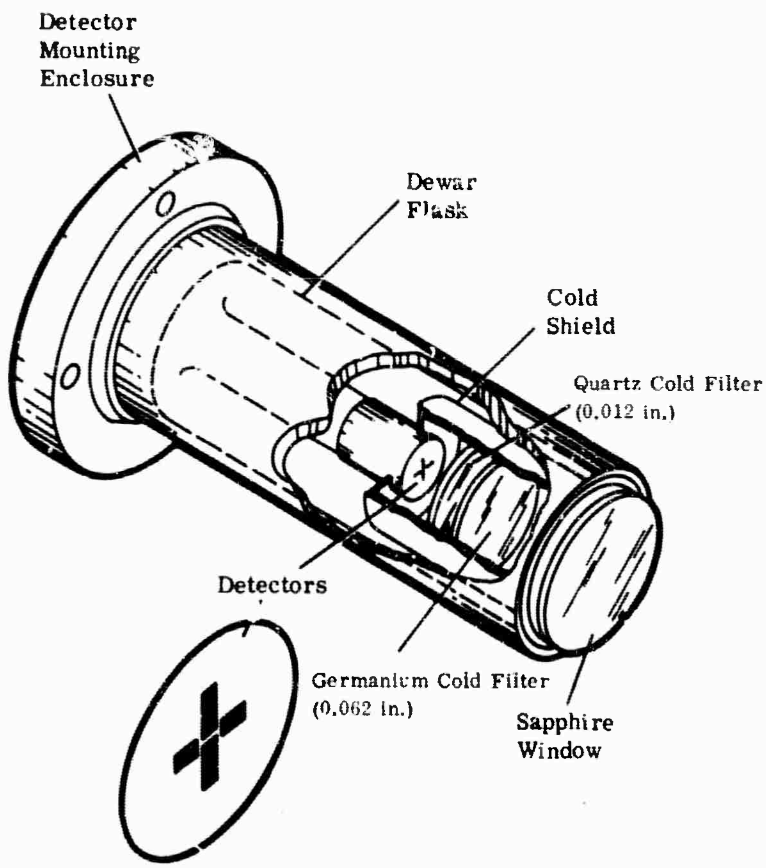


FIGURE 4. CUTAWAY VIEW OF THE PbSe DETECTOR

may be automatically changed at the rate of one per minute. In the "slow elevation" mode, the scanner remains fixed in azimuth, while the scanner's line of sight is moved in elevation at 1°/sec and the filter wheel rotates rapidly; in the "fast elevation" mode, the filters remain fixed, and the line of sight is scanned in elevation at 24°/sec.

Lamps on the control panel indicate main power on, film transport, and calibration cycle in progress. The two meters indicate the filter in position and the detector cell current. Two additional indicators mounted near the aircraft instrument panel show scanner azimuth and elevation angles. All switching required to operate motors and clutches is accomplished by relays controlled by the mode switch, with interlocking used to prevent accidental damage to the scanner.

2.2.3. CAMERAS. Photographic coverage of the area scanned by the background measurement equipment was accomplished by two cameras. One of these, a 16-mm pulse-type camera

on the lower turret assembly, rotates in azimuth with the scanner. It has a lens with a 10-mm focal length and a resulting field of view $40^{\circ} \times 60^{\circ}$. Since the 40° field of view covers the entire range of the elevation scan, it is not necessary for the camera to scan in elevation; photographs are taken every 60° during the azimuth scans and once at approximately the center of each elevation scan. Kodachrome was used in the camera. The second camera looks beneath the airplane and scans from horizon to horizon. It takes one photograph every 32 sec, normally on 70-mm tri-X film.

2.2.4. ELECTRONICS. Figure 5 shows the scanner's information electronics. Signals are recorded on both the oscillograph carried in the airplane and on an eight-channel tape recorder. The impedance of the detector signals is reduced by cathode followers on the upper turret assembly, then amplified and fed to four channels of the oscillograph and to the tape recorder. One FM tape channel is used for each of the detectors perpendicular to the direction of scan, and a third FM tape channel is used for one of the remaining two detectors, depending upon the scan direction.

Four tone oscillators, operating at frequencies of 765 cps, 1105 cps, 1445 cps, and 595 cps, respectively, generate carriers for the azimuth, elevation, sun-direction, and film-transport data. The modulated signals are added and then recorded on one AM channel of the tape recorder. A second AM channel is used to record filter identification and synchronizing information, while a third records the output of a crystal control oscillator set for the center frequency of the FM channels. The latter channel is used for wow and flutter compensation. The last AM tape channel bridges the pilot's intercom system and records pilot remarks and radio transmissions. The d-c components of these signals (except voice) are also recorded on the oscillograph, along with temperature of the entrance window temperature adjacent to the filter wheel, detector cell current, and aircraft roll and pitch.

2.2.5. SUN TRACKER. An instrument was designed and constructed to be mounted on top of the aircraft for sun tracking. It contains a rotating filter disc and an ambient-temperature PbSe detector and is intended to obtain an estimate of atmospheric transmission between the location of the airplane and the sun. However, since the transmission measurement portion of this instrument was not operational, it was used only to provide sun-azimuth information.

2.3. SCANNER CALIBRATION

Spectral calibration of the entire scanning instrument was performed in the laboratory. System linearity, frequency response, and step-function response were measured prior to each

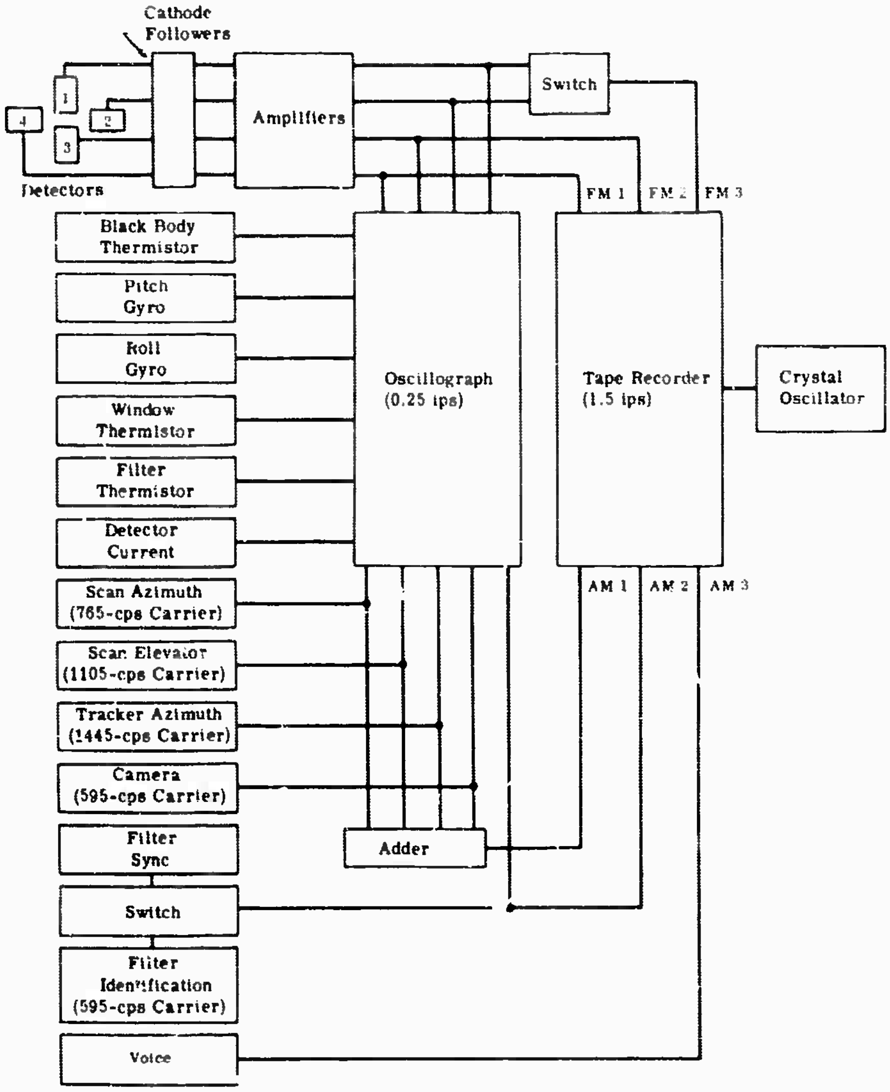


FIGURE 5. BLOCK DIAGRAM OF THE SCANNER'S INFORMATION ELECTRONICS

flight, and energy calibration (using the Jones method) was performed for each filter before and after every flight. An internal calibration was also carried out as part of the preflight and postflight procedure.

The spectral response of the entire system, including the entrance window, was measured in a dry-nitrogen atmosphere at -25°C, and results of these measurements are presented in figure 6. The system's spectral response with each filter is shown normalized to unity response

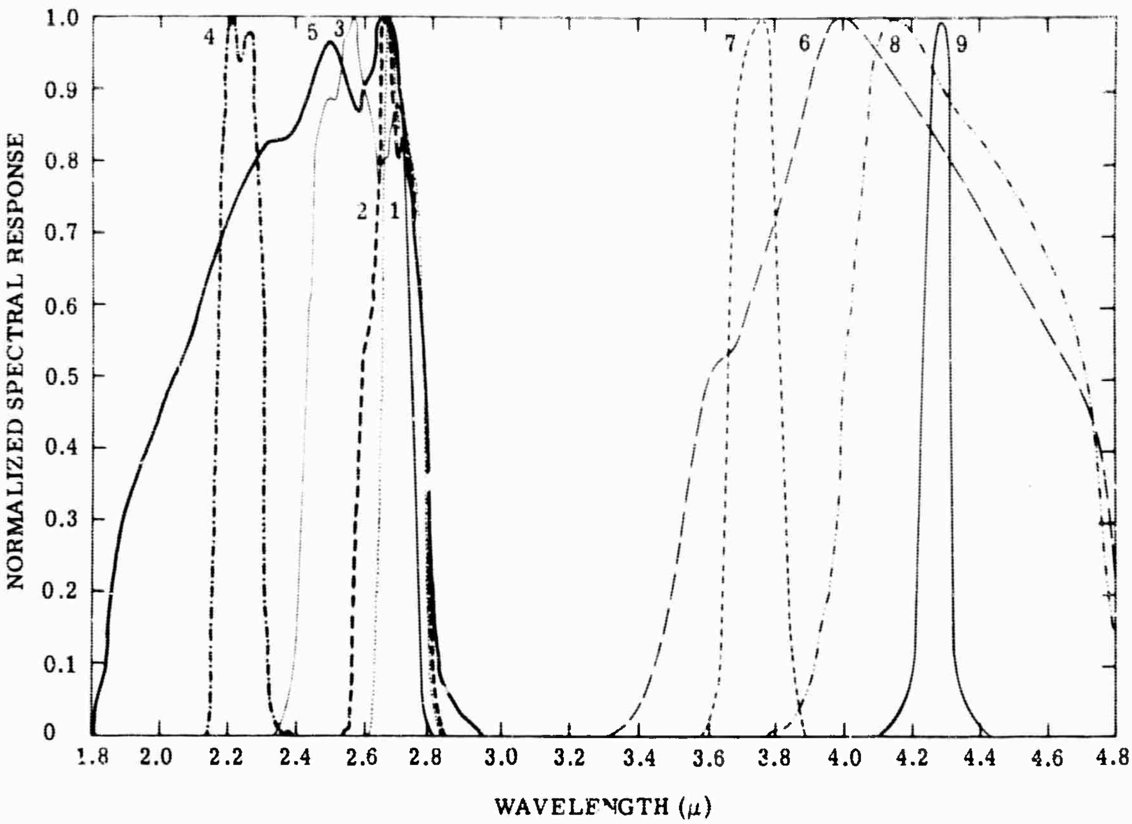


FIGURE 6. NORMALIZED SYSTEM SPECTRAL RESPONSE WITH EACH FILTER. The numbers on the curves are the filter numbers.

at the respective peak values. Departures from unity response are taken into account by the energy calibration prior to each flight.

A 500^{o}K blackbody source was mounted with a variable speed chopper, aperture wheel, and appropriate baffles, and this equipment was used to determine the overall system's linearity, frequency response, and step-function response. The characteristics of the electrical system only were measured by inserting signals from a calibrated microvolter into a dummy detector. Linearity and frequency response were measured with this technique.

Two methods were used to obtain the energy calibration for each filter: the Jones' method [5] and the inverse-square method. The first of these is the more convenient for overall calibration, but the second is the more direct and yields the greater confidence. The results of the two methods agreed to within 5%.

The Jones method depends upon having the detector located at the focal point of the optical system. The calibration source is located just outside the scanner entrance window. Under these conditions, the effective power at the detector is given by

$$P_d = N_{BB} A_{BB} \frac{A_d}{(FL)^2}$$

where N_{BB} = the effective blackbody radiance

A_{BB} = the blackbody area

A_d = the area of the detector being calibrated

FL = the radiometer's focal length

Since this technique makes use of all the optical elements in the system, it provides an overall calibration.

In the inverse-square method, the calibration source is located directly in front of the detector, with no optical elements except the spectral filters intervening. The power at the detector is:

$$P_d = N_{BB} A_{BB} \frac{A_d}{D^2}$$

where N_{BB}, A_{BB}, and A_d are defined as above, D is the distance from calibration source to detector. It is necessary to correct for transmission when comparing the two methods.

The scanner was placed in the internal calibration mode immediately following external calibration to obtain the relationship between the external and internal calibration signals. The internal calibration subsystem then monitors overall system performance during a flight.

3
DIGITIZATION AND PREPARATION OF THE DATA

3.1. DATA DIGITIZATION*

The equipment and techniques used for the data digitization are described here to give the reader a better understanding of the nature of the digitized data. The signals from the data channels were transmitted directly to the digitization equipment. Such signals as the camera pulse, time pulse, azimuth, and elevation signals were processed and then supplied to the digitization equipment.

*The digitization was performed under Lockheed Missile and Space Company Subcontract Purchase Order 28-2613, Prime Contract AF 04(647)-787.

The equipment used for the analog-to-digital conversion may be considered as consisting of two sections: signal playback and processing equipment and Packard Bell digitization equipment, which included a multiplexer, analog-to-digital converter, high-speed buffer, computer (Model 250), and magnetic-tape deck.* Figure 7 is a block diagram of the signal playback and processing.

As mentioned above, the radiance measurements were recorded on a Davies Laboratories (division of Minneapolis-Honeywell) eight-channel airborne recorder using the tape format given in table II. A Davies Laboratories magnetic-tape reproducing system was used to read the data recorded by the airborne tape recorder.

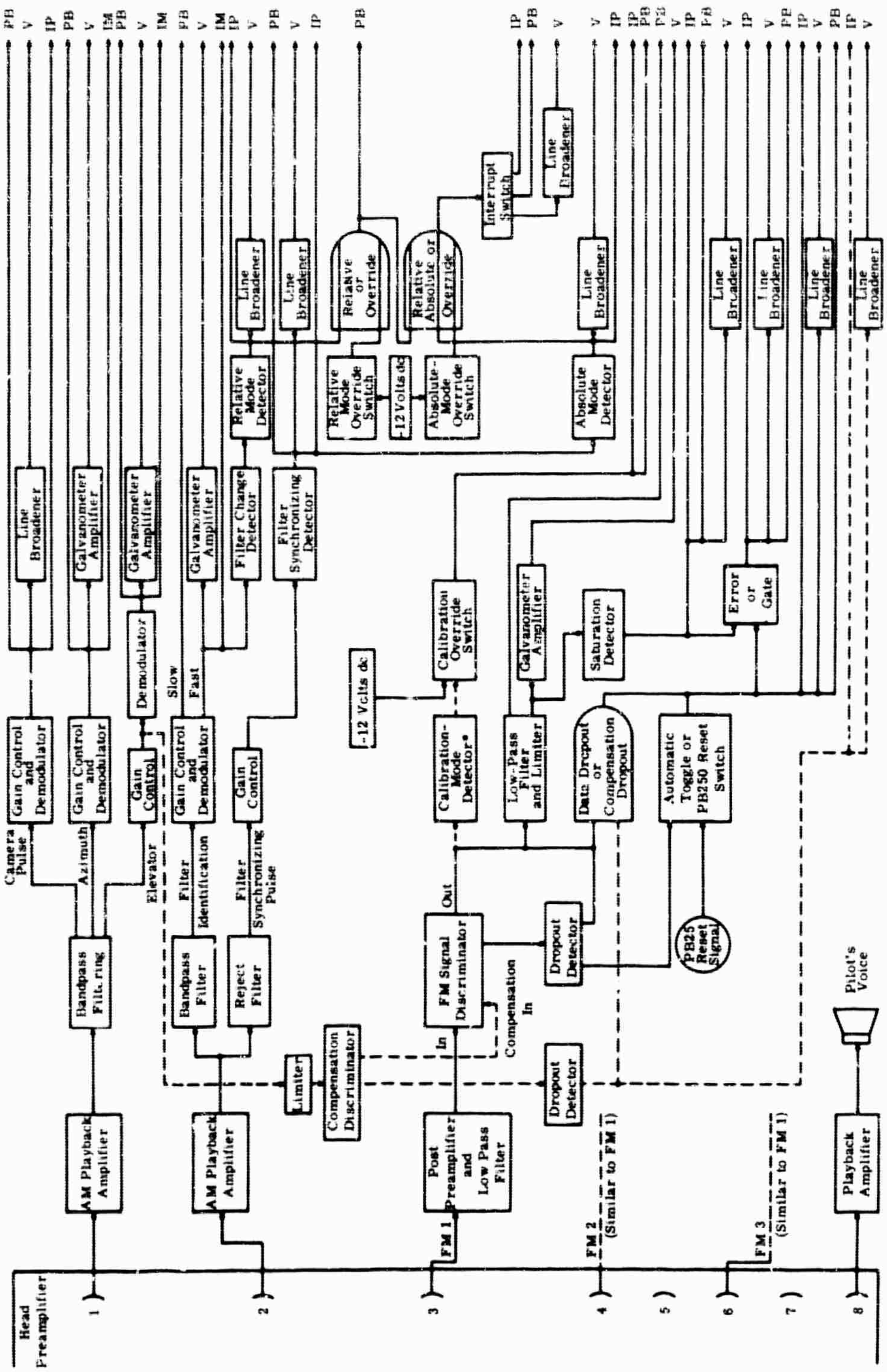
Examination of the FM cell data signals at the output of the preamplifiers showed that the signal level was low and the signal-to-noise ratio poor because of the presence of high-frequency noise. Therefore, a post-preamplifier was designed and built to reject this high-frequency noise.

The initial plan was to play back the recorded data with wow and flutter compensations. It was observed, however, that the compensation reference signal was not present in usable form on a large portion of the data tapes, so an attempt was made to use the elevation carrier frequency (1105 cps) as a reference signal for these compensations. Some of the flights were digitized with this form of compensation, but examination of the data revealed frequent loss of the compensation signal and the introduction of spurious signals arising from dropout of the elevation signal. It was then decided to digitize without wow and flutter compensations. Only the flight of 21 April 1961 was retained in both forms for comparison.

The FM discriminators (Minneapolis-Honeywell Type 5204) were of the cycle-counting variety which compensates for line voltage variations. After being demodulated, the cell data signals were passed through a lowpass filtering network and voltage limiter. The voltage limiter was intended to keep the output voltage within the safe operating range of the multiplexer and analog-to-digital converter even when dropout occurred. The saturation detectors were designed to compensate for the low-frequency rolloff occurring after the airborne amplifier stage had reached saturation and to detect both positive and negative saturations. When saturation was detected, a binary signal was sent to the computer. Operational amplifiers were used in the design of both the lowpass filters and saturation detectors.

Magnetic-tape dropout resulting from wear and dust on the tapes became noticeable. Such anomalies cause the signal discriminators to behave improperly. In effect, under such conditions, sufficient input signal to the discriminator is not available, and this, in turn, causes

*This equipment was leased from Applied Data Systems, Lower Newton Falls, Mass.



PB = PACKARD BELL EQUIPMENT
V = VISICORDER
IP = INDICATOR PANEL
IM = INDICATION METER

*Calibration-Mode Detector Was Only Used with FM 1

FIGURE 7. BLOCK DIAGRAM OF SIGNAL PLAYBACK AND PROCESSING

TABLE II. TAPE-RECORDER CHANNEL FORMAT

Channel	Form	Information Recorded
1	AM	Scanner azimuth (765 cps) Scanner elevation (1105 cps) Solar transmissometer azimuth (1445 cps) Camera film-transport pulse (595 cps)
2	AM	Filter identification and synchronization (595 cps) Transmissometer filter synchronization (1445 cps)
3, 4, 6	FM	Detector-cell frequency response (0.7 to 3000 cps) and dynamic range (40 db)
5	AM	Reference signal of 1.25 kc for wow and flutter compensation in playback
7	FM	Solar spectral radiation data from transmissometer: frequency response (0.7 to 300 cps) and dynamic range (40 db)
8	AM	Pilot voice track (all communications with the pilot as well as pilot's comments).

high-frequency high-amplitude spurious signals at the output. It was, therefore, necessary to devise a scheme permitting carrier amplitude dropout to be detected and labeled in the digitization process. When dropouts were detected, a binary signal was sent to the computer until it acknowledged the error signal and the dropout condition ceased.

It had also been intended that calibration-mode signals would be detected automatically, but when it was discovered that similar signals were also present during relative-mode operation, this approach was abandoned. Instead, a calibration override switch was manually operated, by listening to the pilot's comments and monitoring the output of the FM discriminators on an oscilloscope, whenever the equipment was in a calibration mode.

The camera synchronizing pulse and scanner azimuth and elevation signals were frequency multiplexed on channel 1. Examination of the carrier frequencies showed that upon playback the carrier was 10% higher than when recorded. The capstan speed of the playback transport was checked, and the tape speed was found to be 1.5 ips. To compensate for the slightly slower recording speed, the capstan motor was powered by a power amplifier and audio oscillator The oscillator was set at a frequency which produced the same carrier frequencies in playback as when the data were recorded. Failure to compensate in this manner could have resulted in a 10% time-base error during scans.

The signal from tape channel 2 was fed to both a bandpass filter and a rejection filter. For a relative mode of operation the bandpass filter would allow the filter identification signal to pass to a circuit to indicate the presence of a stationary spectral filter. If a relative mode was not automatically detected, the relative override switch could be used. For an absolute mode of operation the filter identification carrier was not present. Instead, pulses indicating when changes in spectral filters took place were recorded. The pulses from the output of the high-frequency reject filter went to the filter synchronizing detector. In recording the absolute mode, the method of identifying each sequence of ten filters was to generate a positive pulse for the first filter and then to follow it with nine pulses of the opposite polarity for the other filters. At first an attempt was made to detect the pulses of both polarities, but it was discovered that the pulse identifying the first filter was very weak and sometimes absent. A logical circuit was therefore designed to detect the absence of the positive filter-synchronizing pulse. After the filter synchronizing pulses were detected, they were sent both to the computer and to the absolute-mode detector.

Two other signals, the time pulse and the digital record pulse (cf. fig. 8), were incorporated for ease of data reduction.

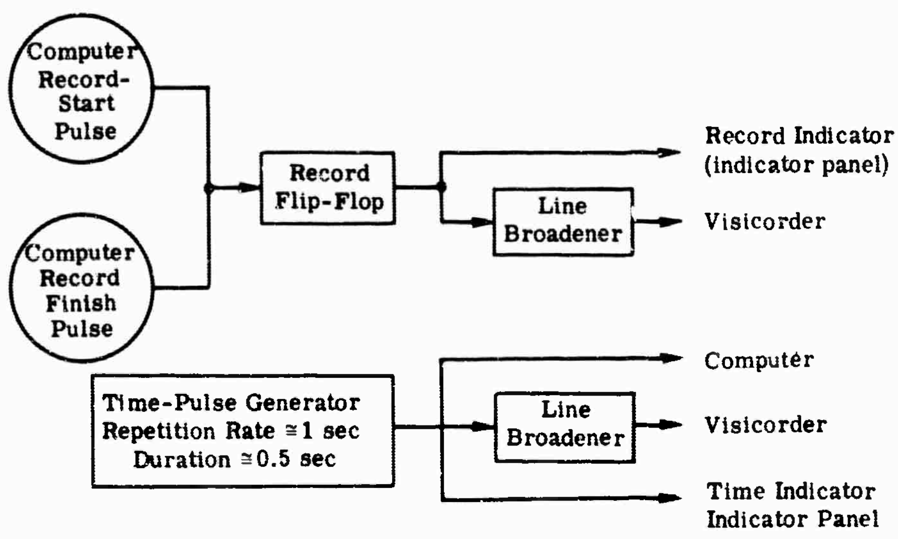


FIGURE 8. BLOCK DIAGRAM OF THE RECORD PULSE (top) AND TIMING PULSE (bottom)

With the exception of the calibration-mode signals, all signals sent to the computer for digitization were also recorded by a Minneapolis-Honeywell visicorder (Type 1108). The resulting oscillograph recordings were developed and made permanent. These recordings pro-

vided a visual means of examining the signals sent to the computer. The visicorder channel format is given in table III. Six of the signals were brought out in analog form, and fifteen were displayed as binary signals. The analog signals passed through galvanometer amplifiers before proceeding to the visicorder. The fifteen binary signals passed through "line broadeners" (2-kc oscillators) before being sent to the visicorder. Whenever a binary signal was present, a rapidly oscillating galvanometer deflection was displayed.

TABLE III. VISICORDER CHANNEL FORMAT. Timing grid intervals are 1 sec; paper speed is 0.5 ips.

Trace*	Identification	Approximate Zero Positions* (in.)	Sensitivity
1	FM 1	0.5	30 v/in.
2	Dropout 1	1.2	0.08 in.
3	Saturation 1	1.4	0.08 in.
4	FM 2	1.9	30 v/in.
5	Dropout 2	2.6	0.08 in.
6	Saturation 2	2.8	0.08 in.
7	FM 3	3.3	30 v/in.
8	Dropout 3	4.0	0.08 in.
9	Saturation 3	4.2	0.08 in.
10	Dropout, Compensation	4.4	0.03 in.
11	Error	4.6	0.08 in.
12	Azimuth	5.1	20 v/in.
13	Elevation	5.6	20 v/in.
14	Filter identification	6.1	20 v/in.
15	Relative mode	6.3	0.08 in.
16	Or	6.5	0.08 in.
17	Absolute mode	6.7	0.08 in.
18	Filter synchronization	6.9	0.08 in.
19	Camera pulse	7.1	0.08 in.
20	Time pulse	7.3	0.08 in.
21	Record	7.5	0.08 in.

*Referenced from top of paper.

Visual monitoring was accomplished simultaneously with digitization by means of meters, indicator lights, and an oscilloscope. The azimuth, elevation, and filter identification signals were displayed on meters; the presence of all other binary signals going to the computer was shown by indicator lights. All signals, particularly the cell data and filter identification and/or filter synchronizing signals, were periodically observed on the oscilloscope.

The Packard Bell equipment digitized the analog data, combined them with the binary signals (error, dropout, etc.), and put them on 1/2-in. IBM magnetic tape. The format of the raw data tapes is given in table IV. Each tape consists of a number of data files terminated by an "end of data" file. Each data file has a four-word lead entry and then groups of four words, each group being noted as a radiance entry. Some files contain as much as a half million words without record mark breaks because the equipment was not capable of buffering. The lead entry contains the analog va[illegible] of the filter; the month, day, and year of the flight; and the tape file number, which runs consecutively from one on for each flight. Each radiance entry consists of four IBM 7090 words. Bits 1 and 13 of each word are sequence bits which allow the determination of the format for the individual word. This acts as a check upon the digitization equipment. Each word has three digitized values: the first contains channels A, B, and C values; the second, azimuth and channels A and B; the third, channel C, elevation, and channel A; and the fourth word contains channels B and C and filter identification. The filter synchronizing bit is 1 if a filter synchronizing pulse was present during the sensing interval, and the time bit is one if a timing pulse was present during this interval. The timing pulses are generated by a free-running multivibrator with 0.5 sec on, 0.5 sec off timing. The camera-pulse bit is 1 when a camera pulse is present, i.e., when a picture is taken. The error bits are 1 if an error is committed in that channel. If an error occurs in a channel, the low-order bit in the channel value is replaced with an error type bit, which is 1 if a saturation error occurred during the last recording interval or 0 if a dropout error occurred. The 36th bit of the fourth word is a calibration bit, which is normally 0, but is 1 for all radiance entries if the calibration signal occurred during that recording interval. The "end of data" file contains four words with all zero bits. The characteristics of the digitization equipment are summarized in table V.

3.2. DATA PREPARATION

Because the raw digitized tapes contain records exceeding the size of the IBM 7090 memory, it was necessary to run them through a "first-pass" program to produce tapes with 500-word records. If the file did not contain an even multiple of 500 words, the last record was filled with dummy words. The first pass also produced a listing and a set of cards which allow the selection of particular tape files. The calibrate files were then processed on the IBM 7090 to obtain the signal amplitude in bits.

Analysis of the card output, data listing, and visicorder records allowed determination of the time, file number, and other details on each data file. This information was punched on cards, and a second-pass data-preparation program then produced tapes which include as the lead entries such information as aircraft altitude and scan direction. These prepared data tapes

TABLE IV. FORMAT FOR THE RAW DATA TAPES

Total Tape Format

Data file
Data file
⋮
Data file
End of data file

Data File Format

7090 Word No.	
1, 2, 3, 4	Lead entry
5, 6, 7, 8	First radiance entry
9, 10, 11, 12	Second radiance entry
⋮	
L-3, L-2, L-1, L	Last radiance entry
	End of file entry

Lead Entry Format

7090 Word No.	Bit No.	Value, Significance
1	1 to 36	All 1's, test
2	1 to 36	All 0's, test
3	1	1 = relative, 0 = absolute
	2 to 26	0, none
	27 to 36	Filter identification value
4	1 to 6	Month
	7 to 12	Day
	13 to 18	Year
	19 to 24	0, none
	25 to 36	Tape file No.

Radiance Entry Format

7090 Word No.	Bit No.	Significance
1	1	Sequence bit (0)
	2	Channel A error bit
	3 to 12	Channel A value*
	13	Sequence bit (0)
	14	Channel B error bit
	15 to 24	Channel B value*
	25	Filter sync bit
	26	Channel C error bit
	27 to 36	Channel C value
2	1	Sequence bit (0)
	2	Not used
	3 to 12	Azimuth value
	13	Sequence bit (1)
	14	Channel A error bit
	15 to 24	Channel A value*
	25	Filter sync bit
	26	Channel B error bit
	27 to 36	Channel B value*

7090 Word No.	Bit No.	Significance
3	1	Sequence bit (1)
	2	Channel C error bit
	3 to 12	Channel C value*
	13	Sequence bit (0)
	14	Camera bit
	15 to 24	Elevation value
	25	Filter sync bit
	26	Channel A error bit
	27 to 36	Channel A value*
4	1	Sequence bit (1)
	2	Channel B error bit
	3 to 12	Channel B value*
	13	Sequence bit (1)
	14	Channel C error bit
	15 to 24	Channel C value*
	25	Filter sync bit
	26	Time bit
	27 to 35	Filter identification value (less last bit)
	36	Calibration bit

End of Data File Format

7090 Word No.	
1, 2, 3, 4	All bits are zero
	End of file entry

*The last bit of the channel value is replaced by an error type bit if an error exists in that channel. The error type bit is 1 if a saturation error occurred and 0 if a dropout error occurred.

TABLE V. CHARACTERISTICS OF THE DIGITIZATION EQUIPMENT

Digital tape speed: 10 ips

Character density: 556 characters/in.

7090 word: 6 characters

Channel A sampling rate: 695 samples/sec

Azimuth sampling rate: 232 samples/sec

contain the radiance value as digitized and multiplied by the proper calibration factor for that particular period. In addition, the data preparation programs determine the scattering angle for each datum. The output format for these prepared data tapes is given in table VI.

TABLE VI. FORMAT FOR THE PREPARED DATA TAPES

(1) There is a hierarchy of data within scan within period within flight. The most important benchmark in this hierarchy is the period.

(2) A new flight is indicated by a change in period date.

(3) All tape records are of fixed length, 500 words (3000 characters).

(4) Each tape will contain one file. A new period will always force a new record.

(5) The period header block gives complete header information for the period and all its scans. Its format is as follows:

Word	Contents	Notes
1	All binary 1's	----
2	Day	Int (integer), D (integer located in decrement portion of IBM 7090 word)
3	Month	Int, D
4	Year	Int, D
5	Hour	Int, D
6	Minute	Int, D
7	Second	Int, D
8	Mode	Int, D
9	Filter	Int, D
10	Sun azimuth angle	FP (floating point, degrees)
11	Sun elevation angle	FP (degrees)
12	Aircraft longitude	FP (degrees)
13	Aircraft altitude	FP (degrees)
14	Aircraft altitude	FP (ft)
15	Cloud altitude	FP (ft)
16	Cloud type	Int, D
17	Cloud fraction coverage	Int, D
18	Aircraft heading	FP (degrees)
19	Fixed angle (elevation or azimuth)	FP
20	No. of scans (N)	Int, D
21	No. of points for scan 1	Int, D
22	a, å for scan 1	These are in left and right halves of word, respectively, where scan angle = a + å(i) for the ith sample of this scan. a is in the format B 17.8; å is in the format B 17.4
20 + 2n-1	No. of points for scan n	n = 1, 2, . . . , N
20 + 2n	a, å for scan n	

TABLE VI. FORMAT FOR THE PREPARED DATA TAPES (Continued)

(6) The data observed during a period begins in word 21 + 2N and continues unbroken through all scans until the end of the period. Each observation requires two words:

Word	Bits	Contents
1	S to 17	Radiance value for the channel A*
1	18 to 35	Radiance value for the channel B*
2	S to 17	Radiance value for the channel C*
2	18 to 29	Scattering angle, B 12.4
2	30 to 31	Channel C: 00, good data; 01, dropout; 11, saturation
2	32 to 33	Same as 30 to 31, but for channel B
2	34 to 35	Same as 30 to 31, but for channel A

(7) Any unused words are filled with 1's.

*Scaling factor for the radiance values:

Filter No.	Scaling Factor
1	B 17.30
2	B 17.30
3	B 17.30
4	B 17.27
5	B 17.27
6	B 17.30
7	B 17.33
8	B 17.30
9	B 17.30
10	B 17.30

The data were put in prepared form to allow easy access to them by those not familiar with all the details of the equipment given above and to those who do not wish to write in machine language but prefer to use Fortran. Under the original digitization contract, Baird-Atomic was not to put data in prepared form, but rather to use them in raw form and write special programs to calibrate the data as required. The greater amount of analysis required by subsequent programs made it desirable to perform calibration only once. A subroutine, called BAGET, which will extract the data from the packed prepared tapes for use with Fortran analysis programs has been written, and its use is described in appendix I.

3.3. DATA STORAGE

All of the data prepared by the first-pass program presently exist in 500-word records on seven-track 1/2-in. magnetic tapes with 800 bits/in. In addition all periods containing data above system noise are in prepared form on magnetic tape with 556 bits/in. A listing of the

periods on tape with ancillary information, probability distributions for the differences between adjacent samples from each channel of each period, visicorder records of all the data for a quick visual review, and a listing of periods with faulty data (e.g., undetected dropout) have also been made available. This data storage bank is currently being held at the Background Analysis Center for future analysis.

4
ANALYSIS OF THE DATA

Some general analysis of the data was performed at Baird-Atomic, and additional general analysis was performed at the Background Analysis Center. In the analysis performed at Baird-Atomic, all the relative radiance data from filters 1 and 2 were used, while the analysis done at BAC used only those periods of data in which the radiances were above system noise. This selection was made at BAC to reduce the required computing time, but it results in correct statistics only for maximum radiance difference and the number of high radiance differences. It was felt by some working on the analysis that the error introduced by this selection process was less than errors introduced by such factors as the lack of adequate meteorological diversity or the varyi reliability of information on cloud type and altitude.

The general analysis performed at Baird-Atomic (reported in ref. 3) included point-source probability distributions, radiance difference distributions of azimuth scan data as a function of elevation angle for fields of view of various sizes; radiance difference distributions vs. latitude, scattering angle, cloud type, and cloud altitude for azimuth scans; and radiance difference distributions as functions of elevation angle and scattering angle for elevation scans. Significant dependences on size of field of view and cloud altitude were found for azimuth scan data, while elevation scan data showed strong dependence on the scattering and elevation angles.

The general analysis performed at BAC is discussed in reference 4 along with results from other experiments. The analysis included obtaining summary statistics on radiance differences for filter 1 as functions of seven ancillary parameters. Crossing-length frequency counts on radiance difference were also included in this analysis, but are not discussed here. They are reported in reference 4 with similar results from other experiments. The radiance differences recorded are differences for a 4×2 field of view, the largest composite field of view possible within the low-frequency cutoff limitations of the system.

The summary statistics on radiance differences for filter 1, given in table VII, are the mean, maximum, total number of observations, and number of high observations. A "high ob-

TABLE VII. SUMMARY STATISTICS AS FUNCTIONS OF SEVEN ANCILLARY PARAMETERS

Cloud Type	Cloud Altitude	Scattering Angle	Look Angle	Sun Angle	Scan Direction	Latitude	Radiance Differences ($w\text{-}cm^{-2}\text{-}sr^{-1}\text{-}\mu^{-1}$) Mean	Maximum	No. of Observations	No. of High Observations
0	1	1	2	2	2	3	0.1285E-06	0.849E-06	11,326	901
0	1	2	2	1	2	3	0.1282E-06	0.9771E-06	6,668	500
0	1	2	2	2	2	3	0.1308E-06	0.7652E-06	4,176	350
0	1	3	2	1	2	2	0.1433E-06	1.101E-06	6,708	779
0	1	3	2	1	2	3	0.1060E-06	0.5122E-06	6,741	244
0	1	4	2	1	2	2	0.1294E-06	0.7708E-06	6,812	590
1	1	1	2	2	2	3	0.0573E-06	0.2397E-06	5,989	0
1	1	2	2	1	1	2	0.1534E-06	0.9837E-06	7,887	1,125
1	1	3	2	1	1	2	0.1011E-06	0.5045E-06	7,842	240
1	1	3	2	1	2	2	0.09426E-06	0.6319E-06	5,552	128
1	1	4	2	1	2	2	0.1496E-06	1.136E-06	6,459	806
2	1	2	2	1	1	3	0.1459E-06	0.6290E-06	1,991	230
2	1	2	2	1	2	3	0.1688E-06	1.538E-06	6,702	1,104
2	1	2	2	2	2	3	0.1818E-06	1.792E-06	13,537	2,485
2	1	3	2	1	1	2	0.1295E-06	1.232E-06	27,236	2,404
2	2	1	2	2	2	3	0.1720E-06	1.936E-06	6,751	2,331
2	2	2	2	1	2	2	0.1778E-06	1.476E-06	6,596	2,028
2	2	2	2	2	1	3	0.1205E-06	0.8988E-06	7,887	1,956
2	2	3	2	1	1	3	0.1693E-06	0.9508E-06	7,203	3,047
2	2	4	2	1	2	3	0.2219E-06	1.159E-06	6 742	3,600
2	2	4	2	2	1	3	0.1342E-06	0.6424E-06	7,738	2,456
3	1	2	2	2	1	3	0.07831E-06	0.3678E-06	7,758	25
3	2	1	2	1	2	3	0.2747E-06	1.729E-06	6,701	3,823
3	2	2	2	1	2	2	0.2602E-06	2.034E-06	10,008	4,536
3	2	2	2	1	2	3	0.2833E-06	5.231E-06	18,442	8,215
3	2	2	2	2	2	2	0.1095E-06	1.836E-06	6,692	1,149
3	2	3	2	1	2	2	0.1518E-06	0.8821E-06	19,705	7,081
3	2	3	2	2	2	2	0.07887E-06	0.4491E-06	6,720	569
3	2	4	2	2	1	3	0.1634E-06	1.054E-06	7,738	3,171
3	3	2	2	1	1	2	0.1777E-06	1.651E-06	6,164	3,871

servation" is a radiance difference exceeding 0.3000E-06. The numbers on the left in table VII represent the coding of the seven ancillary parameters, cloud type, cloud altitude, scattering angle, look angle, sun angle (from the zenith), scan direction (elevation or azimuth), and latitude. This coding was done by ranges as shown in table VIII. A combination of seven range-code numbers describes a particular class of event, and within each class of events the summary statistics are recorded.

The prepared absolute radiance data were not available in time to be incorporated into this report.

TABLE VIII. RANGE CODING FOR THE SEVEN ANCILLARY PARAMETERS USED IN TABLE VII

PARAMETER	Range Code 0	1	2	3	4
Cloud type	No information	Terrain	Water cloud	Ice cloud	
Cloud altitude	No information	0 to 30,000 ft	30,000 to 40,000 ft	>40,000 ft	
Scattering angle	No information	0 to 45°	45° to 90°	90° to 135°	135° to 180°
Look angle	No information	0 to 60°	60° to 90°		
Sun angle	No information	0 to 60°	60° to 90°		
Scan direction	No information	Azimuth	Elevation		
Latitude	No information	20°S to 20°N	20°S to 50°S 20°N to 50°N	50°S to 90°S 50°N to 90°N	

5
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purposes of these measurement and data analysis programs were twofold: first, to develop a model and, second, to estimate system performance statistics. For such parameters as scattering angle and spectral distributions, the data did increase knowledge contributing to the development of a model. However, for such factors as size, cloud type, and cloud altitude, the studies were somewhat less successful in isolating the significant parameters. Although some attempt at obtaining system performance statistics was made (cf. ref. 3), the measurements did not cover a sufficiently wide range of parameters to adequately duplicate an operational system environment.

The major conclusions pertaining to a radiometric model are presented in detail in reference 3. That report contains results on joint distribution of radiance difference and cloud type, cloud altitude, direction of scan, field-of-view size, spectral interval, and scattering angle. As expected from theory, high clouds, low scattering angles, scans across the horizon, a wide

spectral interval, and large fields of view gave higher radiance gradients. The cloud-type findings were inconclusive.

Many additional conclusions and recommendations were arrived at during the more extensive data preparation and analysis at BAC. These resulted from trying to extract parametric relations in addition to those of reference 3 and a better understanding of the results presented there. It is felt that these conclusions and recommendations should be published as an aid to future experimenters and to provide insight on the validity of data from this experiment and other related ones. Most of the shortcomings evident here also occur in most other experiments in this area, aerospace remote sensing. Certain of the conclusions are of a general program nature and involve the planning of experiments; some are associated more specifically with equipment; and others involve considerations of data gathering and reduction. They are presented below in that order.

The general direction of this program has changed many times during execution because of the results of flights and data reduction. A review of these changes indicate that certain goals are not consistent with the nature of the physical problem, the equipment, and the personnel; therefore, the following conclusions and recommendations on general goals for the gathering of radiometric cloud statistics are indicated.

From a review of the entire program, it appears more desirable to fund additional flights for data gathering than to expend a great amount of money to rectify errors and oversights in measurements already made. Three to five years of data gathering and simultaneous reduction seem necessary for refining an instrument and data reduction techniques to produce satisfactorily reliable data, i.e., data with error rates less than 1 in 10^8.

If the program is to produce data useful for system statistics estimation, gathering of a large quantity of data should be anticipated. If the program is to provide information on such physical parameters as scattering angle, special locations and a selection of seasons are required to isolate specific cloud types, altitudes, and meteorological conditions. The two goals are not compatible in a single experimental program. The program should be left flexible, and extra funds allocated to study unanticipated variables discovered during the data gathering. If the data are to be applied to a satellite system, atmospheric transmission above the measurement apparatus must be determined at the time of measurement.

It does not appear that a program of this nature is most desirable for determining size, shape, and occurrence characteristics of clouds because of the limited spatial information obtained even with multi-element arrays. Visual information obtained from photographs or vidicons should be used to gain fundamental knowledge of structured clouds. Present information in the

visible region on cloud structure is poor, and the imposition of nonvisual measurement techniques makes the problem even more difficult.

If the major parameters of cloud reflectance are to be studied, the work should probably be done in a controlled laboratory environment, such as a chamber containing a cloud or aerosol particle mixture, where lighting direction, opacity, etc. can be regulated. Such studies would aid in planning subsequent flights to produce useful information with little redundancy.

Certain general equipment limitations which became evident during this study apply to most aircraft and spacecraft radiometers. These limitations should be taken into consideration in designing and modifying future experiments.

The use of a "null filter" is highly desirable in this work. The one in the equipment used in this particular program was made out of aluminum 1/8 inch thick, which did not pass light and therefore allowed system noise statistics to be measured. Its presence helped in determining system malfunctions during flights because signals received then were produced internally and illustrated to field personnel the need for corrective action.

This equipment also used an internal blackbody for calibration and an opaque shield to give a zero level. Blackbodies contain complex electronics and thermal devices and are not necessary for in-flight calibration. Internal calibration lamps of two levels of intensity are satisfactory for obtaining estimates of the zero level and the gain setting. The use of a zero or opaque shield will provide redundant information, but should nevertheless be included in all experiments.

Consideration should be given to compensating for or calibrating to eliminate the effects of internal emissivity in instruments used. Most systems contain a mask in the center of the entrance mirror optics which provide approximately 25% emissivity over the entire aperture. The emissivity of the rest of the aperture can be as high as 85% because of the large number of mirror surfaces, each of which has at least 5% emissivity, and other elements such as interference filters, gratings, and windows which have an emissivity considerably greater than 10%.

Flight experience with this and similar equipment indicates that it is extremely desirable to maintain the electronics at or near laboratory temperature, 25°C, to avoid any drifts in d-c levels or gains. In addition, optical elements and detectors should be maintained at a constant temperature to avoid drifts in d-c radiometric level and in detector responsivity. Another advantage of this would be to produce constant system noise for all measurements, and thus the sum of system noise over all measurements would be Gaussian (if system noise were Gaussian). If system noise varies from measurement to measurement, the summed distribution of system noise over the entire set of measurements may be peculiarly non-Gauss[illegible] and ma[illegible]k the significant radiometric distributions.

The use of many azimuth or elevation scans within one scan period produced extreme redundancy. For example, during a one-minute elevation scan period there were 30 scans of the same area. When the scanner was pointed forward and even when it was pointed at 90° to the flight path, the redundancy between consecutive scans was well in excess of 20 parts to 1. A redundancy of 2 parts to 1 might be desirable for checking the system, but redundancy such as 20 or more to 1 does not increase the value of the experiment.

The multicell array used in this experiment is highly desirable for studies of field-of-view size. A larger number of cells in the array would be still better.

The equipment for such experiments should always repeat the same sequence of operations; there should be no variation because of manual intervention by the pilot. The sequence can be made short enough to include various types of scans and measurement modes and yet allow items of interest seen by the pilot to be covered by a complete set of measurement modes. Automatic sequencing without manual intervention aids data reduction since it does not require manual interpretation on the ground to specify the nature of each data period. Manual review of data took considerable time during the preparation of data from this experiment. The equipment should also automatically calibrate itself periodically in flight, and calibration should occur for each filter.

The use of a relative-data mode, while allowing collection of a large amount of data (which is also highly redundant data), does not appear generally advisable because of the wide electronic bandpass it requires. Most of the significant bandpass necessary occurs at low frequencies for the system to properly simulate systems with multiple fields of view, and much system noise, such as on-off transients of the equipment and 1/frequency noise of the detector, occur at low frequencies. Unfortunately, absolute measurements require a larger dynamic range than relative measurements because most spatial filtering techniques attenuate signal range by at least 20 db. A dynamic range of 45 db is typical for the best analog tape recorders, so the residual range of the data after spatial filtering will be less than 25 db, which is barely adequate for rare-event statistics.

The use of pulses at scan reversals and multipulse signals at intermediate points is preferable to using analog position data. The analog position data from these measurements proved to be highly noise-infected. The usual recording bandwidth limitations produce poor signal-to-noise ratios in multiplexed analog data. While analog records are an aid in detecting scan nonlinearities, digital (pulse) records are more accurate for determining the time of scan reversal. Positive pulses only, rather than positive and negative pulses, should be used to permit the use of zero-one detection logic in digitizing.

Pilot voice comments and radio communications on tape are extremely useful for determining accurate aircraft position as a function of time. This recording may also contain other information on the visual appearance of the clouds.

Most experiments in this area of study have an equipment range of 60 db or less and data from them can be digitized into 10 bits (2^{10} = approximately 60 db). The use of 13- or 16-bit digitization is probably beyond the range of reliable airborne equipment, but might be practical in the future. It is usually difficult to design equipment with sufficient sensitivity and dynamic range so that the brightest images do not cause equipment saturation while the minimum radiance is significantly above system noise.

If digitization is performed in flight, equipment saturation should be within the range of digitization. In any case, saturation should occur against hard limits, i.e., there should be diodes in the amplifier to produce a sharp cutoff when saturation occurs. This allows easy detection of saturation and, in general, faster recovery of the equipment after saturation. The saturation limits of the equipment should be measured in the laboratory, and there should be a saturation indicator which is only reset after the flight. This will allow a technician to learn immediately after the flight whether any saturation occurred during that flight and hence alert him to improper system-gain settings.

Although analog-to-digital conversion in flight is desirable, failures in the process are hard to trouble shoot, and it is usually difficult to restore the data because the failure of one component may scramble information on all channels. Because aircraft power-supply frequencies vary, digital recording in the aircraft also makes it necessary to check for proper bits-per-inch spacing on the magnetic tape.

If radiometric measurements are to be made at small scattering angles, one of the major problems in equipment design is solar baffling, which is necessary for measurements made at scattering angles less than 90°. It is almost impossible to overdesign solar baffling.

Boresight cameras are a good ancillary means of data collection and recording. Color film should be used to provide a wider range of information, and an ultraviolet filter should also be used if the film is a standard color film, which is extremely sensitive to ultraviolet radiation. It is recommended that infrared color film be tried on certain flights in order to achieve a better understanding of the improved contrast provided by the superior haze-penetration capability of infrared radiation.

Interference filters should be measured on a logarithmic basis to assure that blocking occurs at all wavelengths outside the interval of interest. A range of 10^3 or 10^4 is necessary for filters in absorption bands. All ancillary data recording should be automatic, i.e., it should not

depend upon the pilot. A second camera (e.g., a boresight camera) could be incorporated to look at an instrument cluster and record such information as altitude and heading, date, and time. Date and time should be recorded on all recording media, camera films, magnetic tapes, pilot logs, etc. In particular, time pulses should be recorded on the prime recording media. Preferably, the time should be recorded in universal (Greenwich Mean) time or a similar fixed format for all flights. On film it may be desirable to use the Navy Reconnaissance Ancillary Data Format because equipment associated with it may already be on the aircraft and merely require hooking up to the camera.

A method for measuring solar transmission should also be incorporated into the equipment to allow for variations in overhead transmission values. These values are necessary in extrapolating aircraft measurements to satellite observations.

A very significant limitation in this project was the constraints in data gathering and reduction. While some of these constraints apply only to the particular equipment used in this case, most appear to apply to other experiments as well.

Because of the peculiar scanning program of the system, few high and low scattering angles were measured. Low scattering angles only exist when both the sun and the equipment's line of sight are near the horizon. (For example, scattering angles of less than 90° cannot occur for measurements taken at the nadir.)

Another peculiarity of this scanning geometry is to produce fewer measurements at a 90° scattering angle than at other scattering angles. To understand this, consider the case where the sun is at 45° elevation. An azimuth scan at 80° from the nadir will then yield most data near 45° and 135° scattering angles, while the scattering angle will change rapidly near 90°, causing less data to be produced in that range.

Review of cloud pictures (boresight pictures) has shown that cloud identification is extremely difficult, if not impossible, because most clouds are of an indistinct shape and, in addition, stratus, haze, and/or cirrus layers produce a "washed-out" picture. It was also observed that most cloud formations are a mixture of two or three forms, and unless multiple-layer cloud identification is given for each field of view, only a gross statement about cloud types can be made. During analysis of these data, high radiances were found when the cloud report was "clear." It turned out that the pilot reports meant that 90% of the area was clear of clouds. It has been concluded that it is probably preferable to give a synoptic description of the area rather than a cloud description and to relate the radiometric statistics to the synoptic description.

It may be advantageous to use a fixed-angle scanner with fly-by scanning to get better information on the size of clouds. With this approach, the equipment should include a velocity/

height system. Such a system might consist of two detectors separated by fixed angle along the scan direction. By using the velocity of the aircraft and the time between identical signals, distance to the cloud and then cloud size in units of length rather than angle could be determined.

Aircraft heading information is needed for scattering-angle calculations. The actual flight direction (not heading) is also necessary for flight path determination and in order to use an ephemeris for parameters such as solar elevation angle. It would be helpful if the pilot would state the omni (radio direction) readings at regular intervals. Perhaps a timer which would buzz every fifteen minutes to remind him to give this type of information could be incorporated. He should also obtain such information after every turn.

Roll, pitch, and yaw should be minimized, but should be recorded, although in this particular experiment the equipment resolution was such that the usual roll, pitch, and yaw for steady flight of the aircraft were not significant. A technique should be evolved to prevent any such measurements taken during maneuvering from being included in the final data.

Pre- and post-flight checkouts of the equipment should be recorded on all media if possible. It is also desirable to record on a strip chart during the flight or to reproduce data from the magnetic recording medium on a strip chart immediately after the flight. This will allow immediate field evaluation of system performance and a preliminary estimate of the data values.

The equipment should be designed so that it can be easily taken out of the aircraft; this allows the aircraft to be used for other experiments and also simplifies equipment maintenance. It is realized, however, that certain problems associated with the equipment can only be solved in the aircraft because they are the result of aircraft interference with the equipment. Shared use of aircraft can reduce time pressures and thereby increase the likelihood of proper equipment maintenance. All recordings in all media should have labels on the medium (e.g., a label on the magnetic tape, not on the reel) which indicate the data and time of flight so that there is no chance for a possible confusion between flights.

The composition of the sample measured in experiments such as this will be influenced by pilot, aircraft, and operational considerations. For example, in this program data were not obtained throughout a 24-hr day. There are certain favored flight hours, generally not in the early morning or evening. Measurements should be made during moonlight, however, to verify the low level of radiance anticipated. The pilot will prefer to avoid storms and will not fly near large, towering thunderheads. Furthermore, most measurement programs cannot be carried on through a full season because of such occurrences as hurricanes, snow storms, etc.

Although it may be costly to have the project engineer in the field during the measurement period it is highly advantageous. He generally knows all aspects of the program and can spot

small things wrong which the technicians may overlook or not feel necessary or valuable for data reduction.

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Appendix I
BAIRD-ATOMIC GET-DATA FORTRAN SUBROUTINE SUBPROGRAM (BAGET)

BAGET is a Fortran subroutine subprogram to obtain data in a Fortran program from the prepared data tapes. This is necessary because the data are encoded in a compact form, with two samples per 7090 word, on the prepared tapes. This packing technique allows the data to be contained on 50 reels instead of 200.

This subroutine subprogram has multiple entries, multiple input variables, and multiple output variables. Its five entries require using CALL and the lables BAGETD, BAGET1, BAGET2, BAGET3, and BAGET4.

The input variables are used to designate the read-tape drive or drives. Both the input and output variables are listed in table IX; the labels are given to facilitate writing this specification and need not be used by the programmer. The "use level" indicates which entry inputs or extracts data from these variables. The "data form" is the type of variable, that is, alphameric, floating-point numeric, or fixed-point numeric. The units are the units of the variable, while the "reference" is the variable's zero coordinate. The range is the anticipated maximum and minimum values of the variable.

Table X gives the numeric codes, while figure 9 shows the data hierarchy. A period consists of all the samples taken for a given filter in the relative mode or a given type of scan (azimuth or elevation) in the absolute mode.

To use BAGET, the following sequence must be observed or BAGET will dump memory and return control to the monitor system. One must CALL BAGET1 (TPN1, TPN2, ASUAZ, etc.) in the order given in table IX. This will establish the tape unit described in TPN1 as the normal input tape drive. If BAGET is to alternate automatically between two tape drives (allowing the operator to change the tape on one drive, while processing occurs from the other), TPN2 must be specified by a two-character alphameric field other than two blanks (bb) or the one specified in TPN1. All the parameters specified in the table must be given at this time so that no variables need be used with other entrances. BAGET1 may be called again in the program, and it will reinitiate all BAGET routines and rewind the tape drive it had been using.

To obtain information which remains invariant during a period, the entrance BAGET2 must be used. This will give information on the next period on the tape, or, if the previous period was the last period on that tape, it will proceed to the next tape. If after analyzing the information provided by BAGET2, the programmer wishes to go to the next period without asking for data, he merely calls BAGET2 again. If the programmer wishes to backspace one period instead of advancing one (as BAGET2 does), he uses the entrance BAGET3. The operation of BAGET3

TABLE IX. BAGET CALLING SEQUENCE

Label	Description	Use Level	Data Form: Alphameric	Data Form: Floating Point	Data Form: Fixed Point	Units	Reference	Range: Low	Range: High
TPN1	Normal input Tape drive (A2)	1	x			Channel drive		A1	B9
TPN2	Alternate input Tape drive (A2)	1	x			Channel drive		bb	B9
ASUAZ	Absolute sun-azimuth angle	2, 3		x		degrees	True North	0	360
SUNEL	Sun elevation angle	2, 3		x		degrees	Horizon (90° from nadir)	-3	+90
ALONG	Aircraft longitude	2, 3		x		degrees	West of Greenwich	0	360
ALAT	Aircraft latitude	2, 3		x		degrees	Equator	-90	+90
AALT	Aircraft altitude	2, 3		x		feet	Mean sea level	50,000	70,000
AHED	Aircraft heading	2, 3		x		degrees	North	0	360
CALT	Cloud altitude	2, 3		x		feet	Mean sea level	0	90,000
ICTYP	Cloud type	2, 3			x	---	Table X, Cloud Type	0	15
ICFRA	Fraction of cloud cover	2, 3			x	tenths	---	0	10
ITH	Time (hr)	2, 3			x	hours	GMT	00	24
ITM	Time (min)	2, 3			x	minutes	GMT	00	59
ITS	Time (sec)	2, 3			x	seconds	GMT	00	59
IDD	Date (day of month)	2, 3			x	days		01	31
IDM	Date (month)	2, 3			x	month		01	12
IDY	Date (year)	2, 3			x	year		60	61
MODE	Mode and detector	2, 3			x	---	Table X, Mode	1	6
NFIL	Filter Number	D, 2, 3			x	---	Table X, Filter	1	10
AVAZ	Absolute viewing azimuth angle	D, 2, 3		x		degrees	True North	0	360
VEL	Viewing elevation angle	D, 2, 3		x		degrees	Nadir	60	95
DA	Data from channel A	D		x		$w/cm^2 sr$	---	0	10^{-3}
DB	Data from channel B	D		x		$w/cm^2 sr$	---	0	10^{-3}
DC	Data from channel C	D		x		$w/cm^2 sr$	---	0	10^{-3}
JA	Error, channel A	D			x	---	Table X, Data Error	-1	+1
JB	Error, channel B	D			x	---	Table X, Data Error	-1	+1
JC	Error, channel C	D			x	---	Table X, Data Error	-1	+1
SCAT	Scattering angle	D		x		degrees	---	0	180
X	End of data sequence	D			x	---	Table X, End of Data Sequence	0	5
LSPACE	Data spacing	2, 3			x	Observation	---	1	1000

TABLE X. BAGET NUMERIC CODES

Cloud Type

(Positive cloud type indicates cloud data obtained from analysis of boresight photographs; negative cloud type indicates the source of cloud data was pilot comments or synoptic meteorlogical reports.)

No.	Type
0	Indeterminate
1	"Towering" cumulus (0 to 15,000 ft)
2	Cumulonimbus
3	Cirrus
4	Stratus
5	Altocumulus
6	Stratocumulus
7	Cirrostratus
8	Altostratus
9	Cirrostratus
10	Haze
11	Noctilucient
12	Clear, no clouds
13	Cumulus
14	Terrestrial Phenomena (e.g., ice cap or mountain tops)
15	Other unusual phenomena

Filter

Filter No.	Wavelength (μ)	Type
1	2.65 to 2.80	1
2	2.55 to 2.80	2
3	2.40 to 2.80	3
4	2.20 to 2.30	5
5	1.8 to 3.0	7
6	3.50 to 4.70	8
7	3.70 to 3.90	6
8	4.00 to 4.70	9
9	4.25 to 4.35	4
10	Opaque	

TABLE X. BAGET NUMERIC CODES (Continued)

Mode

No.	Data Base	Scan Direction	Detector
1	Absolute	Azimuth	PbS
2	Absolute	Elevation	PbS
3	Relative	Azimuth	PbS
4	Relative	Elevation	PbS
5	Relative	Azimuth	PbSe
6	Relative	Elevation	PbSe

End of Data Sequence

No.	Interpretation
0	Data just transmitted are not the last sample in the present sequence
1	Data just transmitted are the last sample in the present scan
2	Data just transmitted are the last sample in the present period, but not on the tape
3	Data just transmitted are the last sample in the present period and on the tape
4	Data just transmitted are the last sample in the present flight, but not on the tape
5	Data just transmitted are the last sample on the tape and for the flight
6	Data just transmitted are the last sample of all available data
7	A read redundancy has occurred

Data Error

No.	Error
-1	Saturation
0	No error
+1	Dropout or invalid

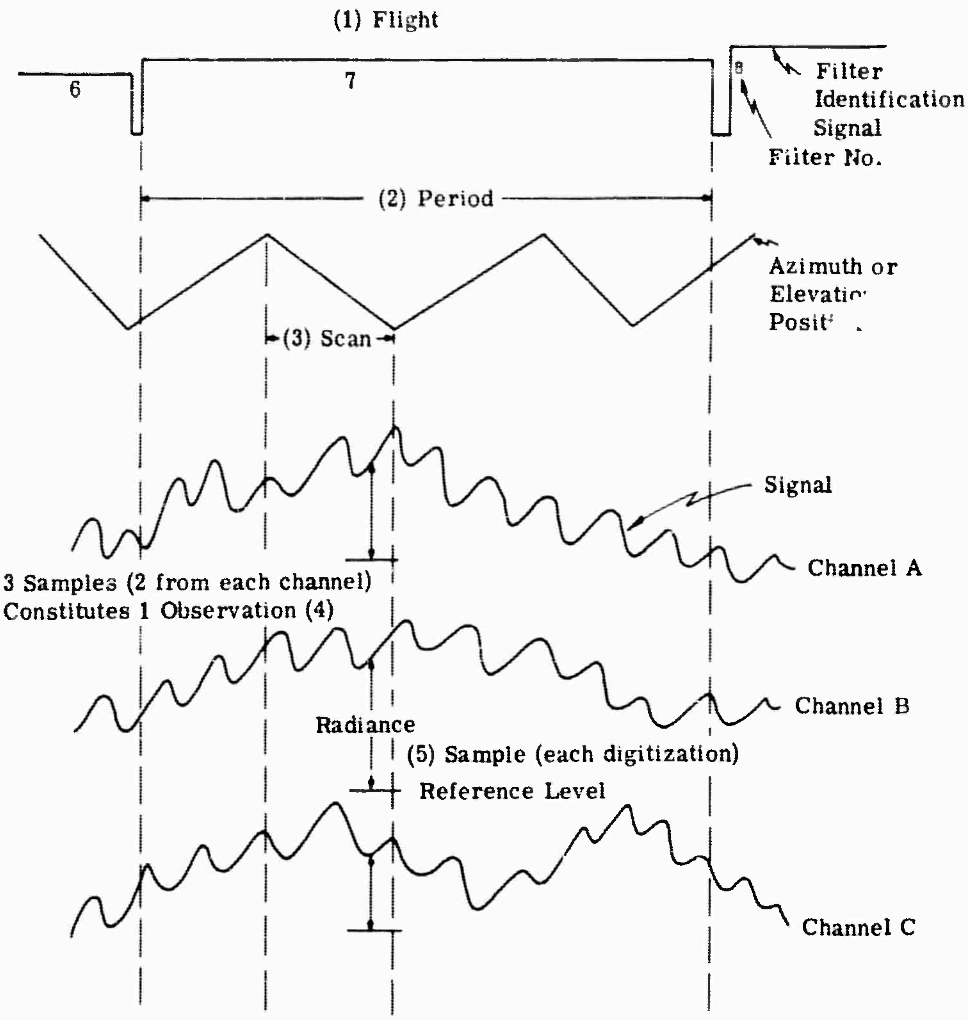

FIGURE 9. DATA HIERARCHY. The numbers in parentheses indicate the hierarchy level.

is identical to that of BAGET2 except for tape direction, but it will not backspace to the previous tape.

To obtain a single set of data samples from the period for which BAGET2 or BAGET3 supply information, the entrance BAGETD is used. To obtain every observation, LSPACE must be set to 1 when calling BAGET2 or BAGET3; to obtain every nth observation, LSPACE must be set to n. Because of the method of checking tape-redundancy error in Fortran, it is necessary to use the entrance BAGET4 between any use of BAGET and any Fortran output statement.

To obtain data from all filters in absolute periods, NFIL must be set to 0 before calling BAGET2 or BAGET3. To obtain data from only one filter in absolute periods, NFIL must be set to the desired filter number before calling BAGET2 or BAGET3.

The following are the legitimate sequences of BAGET entrances which do not produce errors:

BAGET1: May be entered at any time.

BAGET2: May be entered after BAGET1, BAGET2, BAGET3, BAGET4, or BAGETD.

BAGET3: May be entered after BAGET2, BAGET3, BAGET4, or BAGETD.

BAGET4: May be entered after BAGET1, BAGET2, BAGET3, BAGET4, or BAGETD.

BAGETD: May be entered after BAGET2, BAGET3, BAGET4, or BAGETD. Unless BAGET2 or BAGET3 is interposed, BAGETD must not be entered after the last information for a period is obtained.

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13 ABSTRACT

Infrared background-radiance measurements obtained from a U-2 aircraft platform were digitized and prepared for analysis with ancillary data such as cloud type and scattering angle incorporated. The final prepared form described in this report allows easy access to the data by using an IBM 7090 computer or other computers which can read seven-track, 1/2-in. IBM binary tape format at 556 bits/in. A data unpacking subroutine written in assembly language for the 7090 is also described. Some results of analysis of these data are presented here, and other analysis results are referenced.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Clouds						
Infrared scanning						
Data						
Data preparation						
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